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A STATE-OF-THE-ART REVIEW OF ENHANCED PERSONAL PROTECTION EQUIPMENT OPTIONS

ANALYSE DE POINTE DES OPTIONS EN MATIÈRE D'ÉQUIPEMENT DE PROTECTION INDIVIDUELLE ACCRUE

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Abstract

The purpose of this study was to conduct a state-of-the-art review of commercial and military off-the-shelf (COTS/MOTS) options for enhancing protection of the soldier's torso, neck, nape and extremities, including any design options from industrial and sports applications. This review was then used to recommend which add-on torso and extremity components should be modeled in Digital Biomechanics software. Finally, detailed requirements for the commencement of a future biomechanical modeling analysis were provided.

Résumé

Cette étude constitue une analyse de pointe des différents articles offrant une protection individuelle accrue du torse, du cou, de la nuque et des extrémités, disponibles dans le commerce ou militaires standards (COTS/MOTS). Des articles conçus pour l'industrie et les sports ont également été inclus dans l'étude dont les résultats ont permis de recommander quels éléments complémentaires de protection du torse et des extrémités devaient être intégrés au logiciel de modélisation biomécanique. Enfin, on a défini des exigences détaillées pour une future analyse du modèle biomécanique.

Executive Summary

Changing threats on today's battlefield have made it necessary to revisit the armor coverage and level of protection of the Personal Protective Equipment (PPE) worn by today's mounted and dismounted soldiers. In order to develop a knowledge base of the current protective equipment options being worn for military, industrial and sports applications, a state-of-the-art review of commercial and military off-the-shelf (COTS/MOTS) options was conducted. The review focused on enhanced protection for the soldier's torso, neck, nape and extremities.

An assessment of many COTS products revealed that it may be more valuable to focus on products that are currently used by infantry soldiers. COTS products from different applications (sports, industrial, etc) may not be as compatible with currently worn Canadian equipment and may require more modification than products already in use by infantry soldiers.

Findings from the review were used to generate a recommendation for digitally modeling various protective equipment components for biomechanical analysis purposes. The recommendation provides examples of how to model the equipment in 5 different ensembles or levels of coverage. The ensembles range from a reasonably low level of coverage, which includes added throat and nape, shoulder, groin and lower back soft-armor protection, to the highest level of coverage, which includes full limb soft-armor protection and hard-armor protection on the shoulders, thighs and sides of torso.

A directive for completing a biomechanical analysis of the body armor components was also provided. The directive lists integral details to consider for completing an analysis that will enable the down-selection of ensembles for prototype development and a future human factors field trial. A trial plan for a human factors field trial was created and can be found in Annex B.

Sommaire

Les nouveaux dangers des champs de batailles contemporains ont rendu nécessaire un nouvel examen de l'équipement de protection individuelle (EPI) que portent les soldats embarqués ou débarqués. Afin d'élaborer une base de connaissances, on a procédé à une analyse de pointe des divers éléments de l'équipement de protection individuelle, disponibles dans le commerce ou militaires standards (COTS/MOTS) utilisés par les forces armées, l'industrie et les sports en mettant l'accent principalement sur les éléments de protection accrue du torse, du cou de la nuque et des extrémités des soldats.

Une évaluation des articles commerciaux standards (COTS) a révélé qu'il valait mieux mettre l'accent sur les articles qu'utilisent actuellement les fantassins. En effet, les articles COTS utilisés dans d'autres secteurs comme les sports et l'industrie ne sont pas toujours compatibles avec l'équipement canadien actuel et pourraient nécessiter plus de modifications que les articles qu'utilisent présentement les fantassins.

Les résultats d'analyse ont permis de recommander la modélisation numérique de divers éléments de l'équipement de protection aux fins d'une analyse biomécanique. Le document présente des exemples qui illustrent comment modéliser l'équipement groupé en cinq ensembles ou niveaux de couverture différents. Les ensembles allaient du niveau relativement faible de couverture incluant une protection additionnelle de la gorge et de la nuque, des épaules, de l'aine et une plaque de protection souple du bas du dos, jusqu'au plus haut niveau de protection comprenant les ensembles souples de protection complète des membres et les plaques rigides couvrant les épaules, les cuisses et les côtés du torse.

On a également donné des directives quant à la façon de procéder pour effectuer une analyse biomécanique des éléments constituant la combinaison de protection. Elles contiennent la liste intégrale des détails à examiner pour mener à bien une analyse qui permettra de restreindre le nombre d'ensembles nécessitant le développement de prototype en vue d'essais ergonomiques et de futurs essais sur le terrain. Le plan d'essai élaboré à cette fin est présenté en annexe B.

Table of Contents

1 Introduction and Product Review

The nature of the threat from Improvised Explosive Devices (IED) has changed the pattern and probability of injury for both mounted and dismounted personnel. Some potential IED effects might not have been accounted for in current designs of PPE (Personal Protective Equipment). The synergistic effects of close-in blast, high density fragmentation and larger fragments have required that armor coverage and the level of protection be revisited.

In order to develop PPE recommendations to overcome any change or increase in vulnerability, and to assess the associated physiological and mobility trade-offs, the biomechanical impact of increasing coverage needs to be assessed. While the Clothe the Soldier protection items and UOR-purchased in-theatre PPE (comprising CG 634 helmet, CTS visor and ballistic eyewear, fragmentation protective vest) will be used as the baseline for this assessment, a better understanding of commercially available add-on armor is necessary.

The purpose of this study was to conduct a state-of-the-art review of commercial and military off-the-shelf (COTS/MOTS) options for enhancing protection of the soldier's torso, neck, nape and extremities, including any design options from industrial and sports applications. This review was then used to recommend which add-on torso and extremity components that should be modeled with biomechanical analysis software. Finally, detailed requirements for the commencement of a future biomechanical modeling analysis are provided.

1.1 COTS/MOTS Review

A review of current state-of-the-art commercial off-the-shelf (COTS) and military off-the-shelf (MOTS) products was completed and is presented in Annex A. A COTS product is one that is available "as-is," whereas a MOTS product requires a commercial vendor to adapt the product to specific military requirements. Many COTS products were found, however their compatibility with Canadian equipment such as the current fragmentation protective vest was usually unknown. It is likely that products currently used by infantry soldiers will require less modification than the products that come from an entirely different commercial or sporting application, such as land mine or ordinance clearing, hockey and football.

This review focused on enhanced protection and did not include helmets or common ballistic vests (with front and back plates). However, state-of-the-art ballistic vest add-on protection products (such as side SAPI plates) were included.

Annex A is divided into four sections:

A. Full Body Systems

B. Upper Limb Protection

C. Lower Limb Protection

D. Other Protection

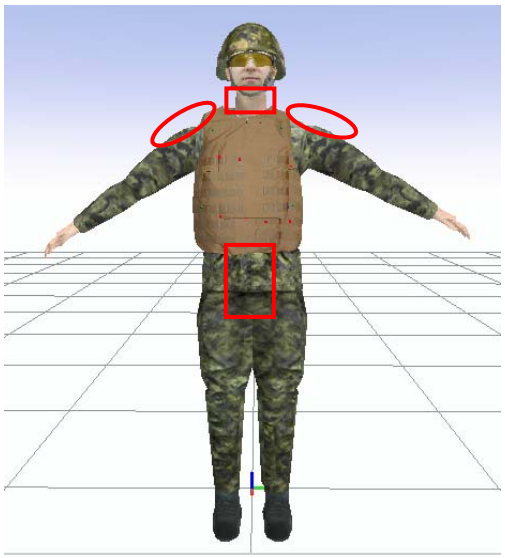
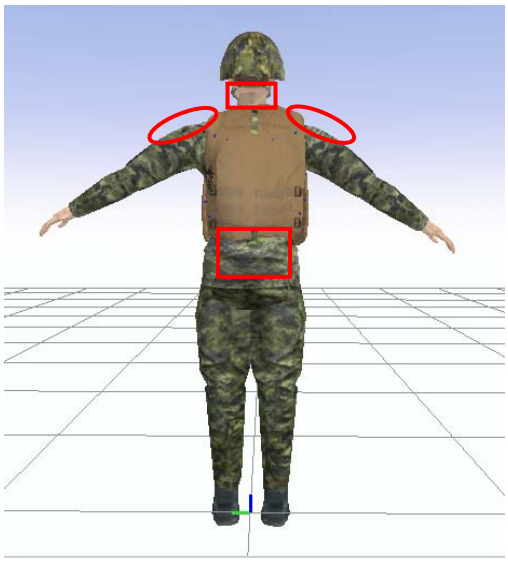
2 Recommendations for Biomechanical Analysis

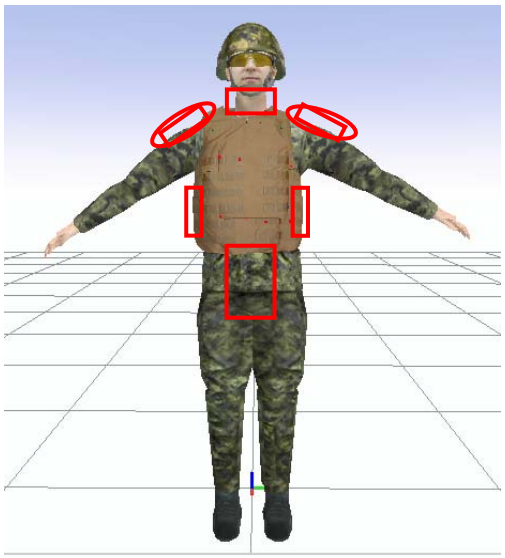
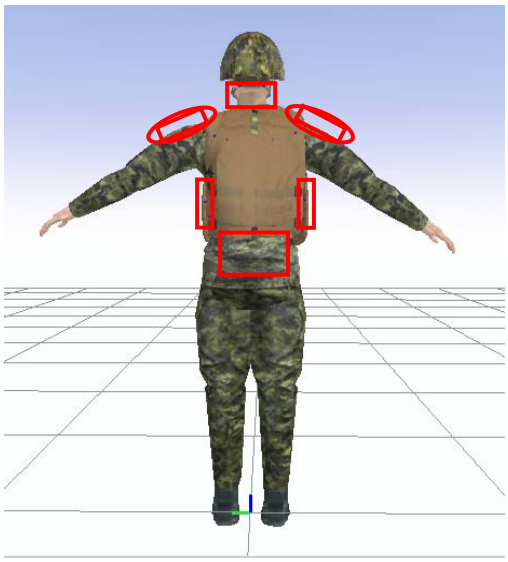
Commencement of a biomechanical analysis is dependant on obtaining digital models of the equipment and configuring the biomechanical analysis software for the specific purposes of this study.

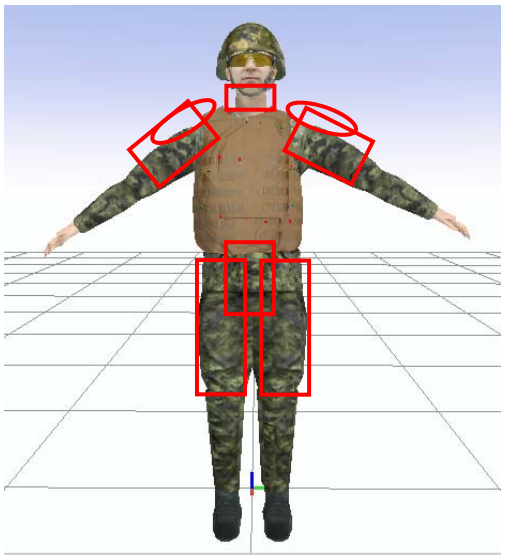
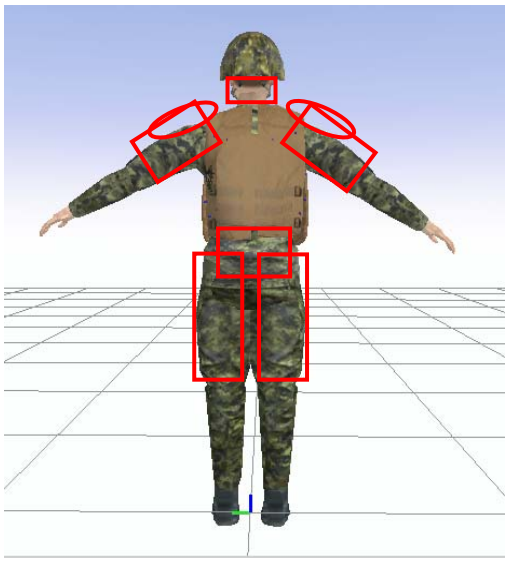
2.1 Digital Equipment Modeling

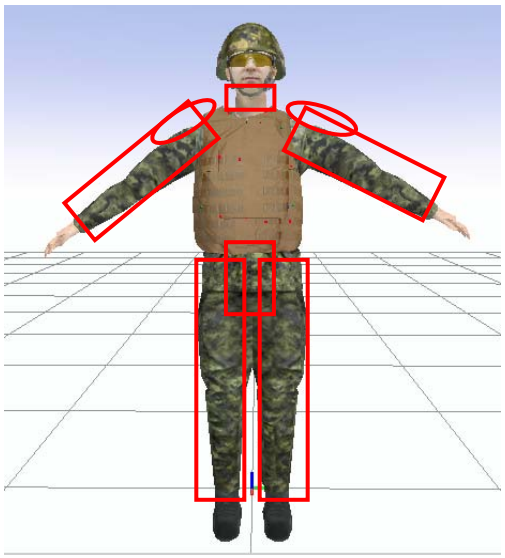
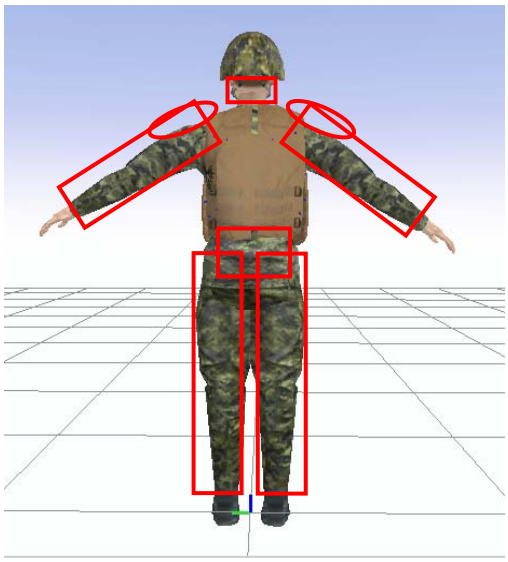
Based on the state-of-the-art review, it is proposed to model the armor in 5 ensembles as follows:

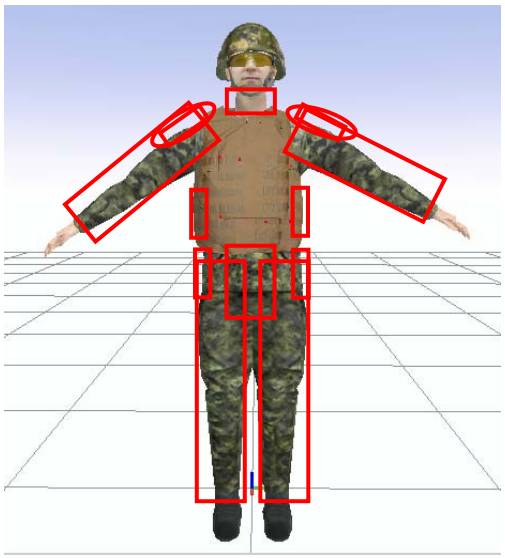
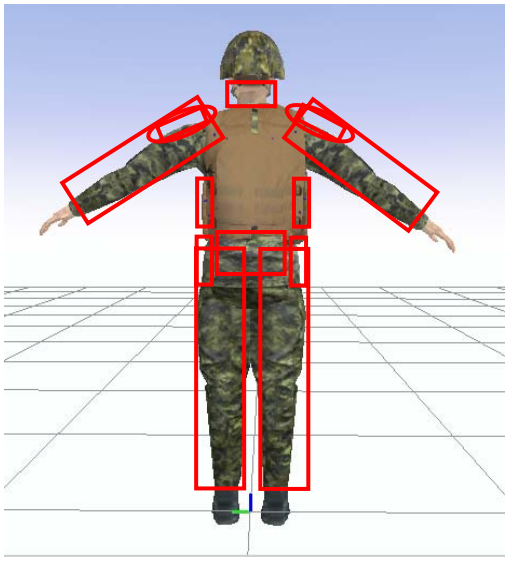
1	**Baseline Equipment:** CG 634 helmet, CTS visor and ballistic eyewear, fragmentation protective vest with front and back plates. Maximum mobility, least amount of protection.	 	**Coverage:** Fragment protection for head and torso front/back. Small-arms protection for front and back of torso. **Need to model:** CTS visor

2	**Equipment:** Ensemble 1 plus soft armor on shoulders/ upper arm, groin protector, throat guard (front of neck), collar (back and sides of neck), and back extension.	 	**Coverage:** Fragment protection for head, neck and throat, shoulders/ upper arms, torso front/back, groin, and lower back. Small-arms protection for front and back of torso. **Need to model:** - shoulder/ upper arm protectors - groin protector - throat guard - collar - back extension. All additions to baseline equipment are soft armor (i.e. no plates). **COTS / MOTS Reference:** Annex A-20, A-21, A-27, A-38, A-39, A-42, A-43, A-44

3	**Equipment:** Ensemble 2 plus hard armor plates on sides and shoulders.	 	**Coverage:** Fragment protection for head, neck and throat, shoulders/ upper arms, torso front/back, groin, and lower back. Small-arms protection for front/back/sides of torso and shoulders. **Need to model:** - Side plates - Shoulder plates **COTS / MOTS Reference:** Ensemble 2: Annex A-20, A-21, A-27, A-38, A-39, A-42, A-43, A-44 Hard Armor plates on sides and shoulders: A-20, A-45

4	**Equipment:** Ensemble 2 plus partial upper and lower limb protection.	 	**Coverage:** Fragment protection for head, neck and throat, shoulders, upper arms, torso front/back, groin, lower back, and thighs. Small-arms protection for front/back of torso. **Need to model:** - Partial-length limb protectors (fragment protection) **COTS / MOTS Reference:** Ensemble 2: Annex A-20, A-21, A-27, A-38, A-39, A-42, A-43, A-44 Partial upper and lower limb protection: A-7, A-18, A-21, A-23, A-25, A-26, A-31, A-41, A-46

5	**Equipment:** Ensemble 2 plus Upper and lower limb protection.	 	**Coverage:** Fragment protection for head, neck and throat, shoulders, upper limbs, torso front/back, groin, lower back, and lower limbs. Small-arms protection for front/back of torso. **Need to model:** - QuadGard or similar full-length limb protectors **COTS / MOTS Reference:** Ensemble 2: Annex A-20, A-21, A-27, A-38, A-39, A-42, A-43, A-44 Upper and lower limb protection: A-3, A-5, A-12, A-14, A-16, A-18, A-22, A-33

6	**Equipment:** Ensemble 3 plus upper and lower limb protectors and hard armor thigh protectors. Least amount of mobility, maximum protection	 	**Coverage:** Fragment protection for head, neck and throat, shoulders, upper limbs, torso front/back, groin, lower back, and lower limbs. Small-arms protection for front/back/sides of torso, thighs, and shoulders. **Need to model:** - thigh protectors (hard armor plates) **COTS / MOTS Reference:** Ensemble 3: Annex A-20, A-21, A-27, A-38, A-39, A-42, A-43, A-44, A-45 Upper and lower limb protection: A-3, A-5, A-12, A-14, A-16, A-18, A-22, A-33 Hard armor thigh protectors: A-7, A-31, A-46

2.2 Biomechanics Analysis Software Development

Biomechanics analysis software will require configuration for this assessment. It is necessary that the following concepts be worked out with the software developer:

Phase A

1. Confirm clothing ensembles
2. Develop the "need to model" protection items:
   2.1. Determine product specifications such as dimensions and weight. This will likely involve acquiring the equipment for direct measurements.
   2.2. Create digital models for the virtual analysis environment.
3. Model the interaction of the armor pieces with the digital human in two ways:
   3.1. The additional armor will affect the weight applied to links of the digital human

   Some additional armor will affect the joint stiffness of specific joints of the digital human. It is likely that most of the equipment to be modeled will be attached to a specific link and will not encroach on the joints. However, in the case full limb protection (such as QuadGard), a tube is worn around the upper and lower limbs including the elbow and the knee joints. This additional armor will require more force to flex the elbow and the knee.
4. Script files that give the character motion (.script) have been developed for the instance of walking, running, jumping from a 1m platform, and diving to a prone position. Is it likely that these will need to be updated to accommodate for higher loading.
5. Preparation of a hatch gunner position and motion.
6. Configure the output of the software to give Absolute Mechanical Energy for the character.
7. Any further requirements by the software developer for tackling these problems.

Phase B

1. Use biomechanical analysis software to simulate the various equipment ensembles during the specific infantry tasks
2. Provide a comparison of Absolute Mechanical Energy under the various equipment conditions.
3. Assess the relationship between mobility and survivability when considering enhanced armor for infantry soldiers.

Phase C

1. Downselect to those ensembles which are reasonable for mounted and dismounted crewmen.
2. Prototype.
3. Perform a Human Factors field trial (See Annex B: PPE Trial Plan).

Annex A: MOTS and COTS

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Full Body Systems

Upper Limb Protection

Lower Limb Protection

Other Protection

Full Body Systems

1	 	**Developed by:** Naval Research Laboratory (NRL), the Army Research Laboratory (ARL), FS Technology and Oklahoma State University with funding and input from PM-ICE and the Office of Naval Research.
		Weight: 9.5 lbs (4.3 kg) (for size S / M, entire system) Arm guards: 1.6 lbs (0.7 kg) each **Cost:** unknown **Material:** Dyneema (flexible soft armor) **Coverage:** Upper and Lower Limbs, blast protection **Extent Used by Current Forces:** 4500 kits are currently being fielded in Iraq by USMC **Compatibility:** USMC Interceptor OTV, ESAPI, Lightweight Helmet **References:** http://www.marcorsyscom.usmc.mil/SITES/PMICE/Info%20Papers/Combat%20Equip/QuadGard.pdf http://www.nationaldefensemagazine.org/issues/2005/oct/amid_bursting.htm
	QuadGard	**Product Description:** The QuadGard (QG) system was designed to provide ballistic protection for arms and legs in response to blast weapon threats and combat casualty trends in OIF. It is specifically intended to protect a Marine's arms and legs from IED fragmentation threats when serving as gunners on convoy duty. In operational terms, the ballistic protection offered by the QuadGard system can increase the non-lethal and safe operating area around an IED by reducing these minimum stand-off distances from the Marine to the device. An associated reduction in injury severity can mean quicker return to duty (e.g. hours or days instead of weeks), reduced need for intensive medical treatment and rehabilitation (e.g. weeks instead of months), or the difference between injuries producing or not producing amputation disabilities.

2		**Developed by:** Med-Eng. **Weight:** unknown **Cost:** unknown **Material:** unknown **Coverage:** Entire upper body and pelvis **Extent Used by Current Forces:** US Army is currently field testing these suits in Iraq for HMMWV gunners **Compatibility:** Fits over "all sizes of body armor." The Cupola protective ensemble includes a Liquid Circulating Garment (LCG) that attaches to a Vapor Compression Cooling unit. The cooling system includes a quick release. **Reference:** http://www.murdoconline.net/archives/003725.html http://www.med-eng.com/getpdf.asp?id=1100&f=.pdf
	Cupola Protective Ensemble	**Product Description:** The CPE features a heavy face shield and protective neck collar. It fits over a soldier's flak vest and is one of a number of methods the Army is experimenting with to reduce the threat of roadside bombs. The CPE consists of the following: • Base jacket • Sleeves (left and right) with rigid composite inserts (forearm and bicep) • Blast plate assembly – chest and groin • Rear blast plate • Pants and integrated groin protector (IGP) • Removable explosive ordnance disposal collar • Optional neck/nape guard • Visor System worn with Personnel Armor System Ground Troops (PASGT) or Army Combat Helmet (ACH) • Hand Guards

3a	 	**Developed by:** Med-Eng **Weight:** unknown **Cost:** unknown **Material:** unknown **Coverage:** Upper and Lower Limbs, blast protection, optional 6" SAPI plates give extended protection to upper arms (deltoids) and hips. **Extent Used by Current Forces:** unknown **Compatibility:** worn under OTV **Reference:** http://www.med-eng.com/getpdf.asp?id=1100&f=.pdf
	Integrated Dismounted Armor System (IDAS)	**Product Description:** The concept of the Med-Eng IDAS is to provide a modular and scalable Extremity Protection System (EPS) for mounted or dismounted operations. The IDAS is worn under the existing OTV to protect the user against the varied battlefield threats including Fragmentation and Bullets. Rock gravel and concrete are commonly found in roadside IED fragmentation. The IDAS rigid/ flexible armor plates protect the wearer by absorbing the impact of such fragmentation. Heavier fragments are caught by the plates' ballistic properties. IDAS also has insert pockets for 6" SAPI plates on the hips and deltoids for greater ballistic protection. It can be worn in full (with arm and leg armor extensions) or basic configuration.

3b		**Developed by:** Med-Eng **Weight:** unknown **Cost:** unknown **Material:** unknown **Coverage:** Same as IDAS but features heavier base protection in the arms. **Extent Used by Current Forces:** unknown **Compatibility:** worn under OTV **Reference:** http://www.med-eng.com/getpdf.asp?id=1100&f=.pdf
	Integrated Dismounted Armor System (Gunner) (IDAS-G)	**Product Description:** IDAS(G) uses the same armor plates as the standard IDAS but features heavier base protection in the arms to protect against multi-threat injuries from roadside IEDs. The lightweight armor enables vehicle gunners to perform dismounted operations as required without removing protection or losing mobility.

4		**Developed by:** Wright-Patterson Air Force Base. **Weight:** 37 lbs (16.8 kg) **Cost:** unknown **Material:** Ceramic plates (Hard Armor) **Coverage:** biceps, legs and ribs, in addition to the front and back torso. **Extent Used by Current Forces:** field tested in Iraq **Compatibility:** Interceptor OTV **References:** http://www.afmc.af.mil/photos/index.asp?galleryID=360 http://www.nationaldefensemagazine.org/issues/2005/oct/amid_bursting.htm
	“Level 4” Body Armor	**Product Description:** The armor includes a new form of ceramic plate that can withstand more bullet strikes than current plates. It also includes bicep, leg and rib protectors. At 37 pounds the Level 4 is too heavy for foot soldiers but could be useful for convoys.

5a		**Developed by:** Med-Eng **Weight:** unknown **Cost:** unknown **Material:** unknown **Coverage:** Torso, neck, head, upper limbs, lower limbs, pelvis / groin. **Extent Used by Current Forces:** not used by infantry but this technology could possibly be modified. **Compatibility:** not designed to be compatible with current infantry gear **Reference:** https://med-eng.com/sub.asp?id=91
	SRS 5 Mine Clearance Ensemble	**Product Description:** The SRS 5 Suit is a protective system that integrates with the SRS 5 Helmet to form a complete mine clearance ensemble. It is protective against blast-type anti-personnel mines and is ideal for reconnaissance, detection, surveying and prodding operations. This ensemble has been tested against small and large overpressure test series. This enables it to offer protection against the widest range of blast-type anti-personnel (AP) mines. • The SRS 5 demining ensemble accommodates hardwire and wireless communications systems • Demining suit Includes an Integrated Groin Plate (IGP) for frontal chest and groin protection • Retractable Groin Plate for easier kneeling • Emergency extraction capabilities

5b		**Developed by:** Med-Eng **Weight:** unknown **Cost:** unknown **Material:** unknown **Coverage:** Upper body, neck, head, upper and lower limbs, pelvis / groin **Extent Used by Current Forces:** not used by infantry but this technology could possibly be modified. **Compatibility:** not designed to be compatible with current infantry gear **Reference:** https://med-eng.com/sub.asp?id=44
	Explosive Ordinance Disposal (EOD) Suit	**Product Description:** The EOD 9 Bomb Suit and Helmet Ensemble provides modular protection and operational flexibility for EOD and CBRNE missions. This modular Explosive Ordnance Disposal protective platform can be configured in the field by an EOD or IEDD technician based on their threat assessment. • Includes Jacket, Integrated Groin Protector and Trousers (including boot covers) for a complete blast protection ensemble • Integrates with a Chemical Protective Undergarment (CPU) to provide a level of Chem Bio Blast Protection. • Accommodates EOD 9 Helmet Remote Control Module to better control helmet functions • Integrates with the BCS 4 Personal Climate System to provide personal cooling and mitigate risk of heat stress • Groin plate retracts for easier kneeling • Integrated carrying pouch to hold the optional BaquaPak for hydration

		• Available in olive drab (standard colour), navy blue or desert tan, each with black webbing trim • Highly flexible to allow an operator to use Med-Eng EOD Tools **EOD 9 Suit Primary Features** The EOD 9 Bomb Suit builds upon the protective strengths of the EOD 8 Bomb Suit with the physical flexibility of the SRS 5 IEDD Search Suit. **EOD 9 Helmet Primary Features** The EOD 9 Helmet uses two interchangeable visors to enable technicians to configure their CBRNE protective platform in the field, based on their threat assessment. This combines operational flexibility with EOD and Chem Bio Blast protection.

5c		**Developed by:** Med-Eng **Weight:** unknown **Cost:** unknown **Material:** unknown **Coverage:** Upper body, neck, head, lower limbs, groin **Extent Used by Current Forces:** not used by infantry but this technology could possibly be modified. **Compatibility:** not designed to be compatible with current infantry gear **Reference:** https://med-eng.com/sub.asp?id=89
	Lightweight Demining Ensemble (LDE)	**Product Description:** The LDE (Lightweight Demining Ensemble) is a modular suit that provides flexibility and balanced protection against blast type anti-personnel mines. The modular design can be configured quickly and easily depending upon protective requirements. The standard LDE suit comprises an Apron (not to be confused with the Demining Apron) and Trousers. Optional LDE components to enhance chest and groin protection include Sleeves, Back Protector and Ballistic Add-Ons. Apron chest plate integrates with the VBS-250 Visor or LDH Helmet for continuous protection over the upper body, neck and head • Lightweight design reduces heat stress and fatigue • Retractable groin plate for easier kneeling • Trousers include thigh and shin plates for greater protection

6		**Developed by:** Damascus Protective Gear **Weight:** unknown **Cost:** unknown **Material:** Hard outer shell with foam and polyester inner material **Coverage:** Upper body, upper limbs, lower limbs, groin **Extent Used by Current Forces:** not used by infantry but this technology could possibly be modified. **Compatibility:** not designed to be compatible with current infantry gear **Reference:** http://www.damascusgear.com/section/products/flex_force/fx1.html
	FlexForce Hard Shell Crowd Control System	**Product Description:** The #FX-1 FlexForce™ Modular Hard Shell Crowd Control System is for high-threat level riot control, domestic disturbance, and cell extraction. The FlexForce™ design provides protection from blunt force trauma without sacrificing the fit or comfort. The suit is lightweight and is designed to be easy for getting into or out of in a moments notice. The front and back hard shell panels have a modular flex design allowing for all shapes and sizes to fit comfortably with out sacrificing mobility. The forearm guard offers a comfortable elbow portion of the pad, which allows flexibility. The knee/shin guard has a non-slip surface, which keeps you planted in position. The entire kit also comes with its own large nylon bag for storage and transport. Upper Body and Shoulder Protection > Hard shell front and back panels feature Damascus® 3-panel flex design for optimum movement, fit and comfort > 3mm Electrum XK8™ hard shell front and back panels > Modular front and back panels are steel riveted together with Cordura® nylon connector straps which attach by Velcro® > Shock absorbing Protium™ foam with a Polyester mesh covers the chest, back, shoulder, and upper arm > Electrum XK8™ plate with shock absorbing Protium™ foam covers both top of shoulder and upper arm

		> Polyester mesh lines the inside of the upper body and shoulder portion which offers comfort and breathability for long term wear > Reflective Police, Sheriff, or Corrections labels can be attached to the front panel for identification > Adjustable Straps fasten with durable nylon elastic and Velcro® Forearm Protector > Two piece hard Electrum XK8™ outer shell provides flex needed by your forearm and elbow. > Shock absorbing Protium™ foam covered with 420 denier Cordura nylon > Polyester mesh lines the inside which offers comfort and breathability > Adjustable straps fasten with durable nylon elastic and Velcro® Thigh and Groin Protector > Hard Electrum XK8™ outer shell on thigh and hip sections > Shock absorbing Protium™ foam with 150 denier Cordura nylon covers the entire outside > Polyester mesh lines the inside which offers comfort and breathability > Tailbone pad has a Electrum XK8™ plastic plate laminated to the Protium™ foam > Groin section has a inner Electrum XK8™ shell with a Protium™ foam padding and mesh cover > Adjustable Straps fasten with durable nylon elastic and Velcro® Knee and Shin Guards > Hard Electrum XK8™ knee caps with super non-slip grip > Hard shell Electrum XK8™ shin plates with dull black finish to avoid reflection > Heavy-duty reinforced Protium™ foam padded nylon inner support > Inner support riveted to the shin plates for ultimate durability > Multiple adjustable nylon elastic and Velcro® straps give a secure fit > Removable adjustable foot guards Sizing > Each piece of the suit fastens and adjusts quickly with durable nylon straps, Velcro®, and quick connect clips which allows each individual a custom fit. > Available in sizes: MD, LG, XLG, XXLG, XXXLG Gear Bag > Total Dimensions – 24”L x 19”W x 15” H > Interior Dimensions - 24”L x 15”W x 15” H > Two Velcro® storage compartments in the front of the bag > Sides of the bag have envelope pouches > Removable padded shoulder strap

7		**Developed by:** Approved Gas Masks **Weight:** unknown **Cost:** $580 **Material:** Hard outer shell with padded inner material **Coverage:** Upper body, upper limbs, lower limbs, groin **Extent Used by Current Forces:** not used by infantry but this technology could possibly be modified. **Compatibility:** not designed to be compatible with current infantry gear **Reference:** http://www.approvedgasmasks.com/riot-controlexo.htm
	Exotech Riot Control System	**Product Description:** **ExoTech™ Hard Shell Disturbance Control System** Hard-shell protection, can be quickly donned or removed with ease for riot control, cell extractions, or other tactical applications. The ExoTech™ provides substantial protection from blunt force trauma. The contour molded PE outer shell features impact ridges that disperse the brunt of the blows, while EVA foam inner padding cushions the body. Soft brush tricot and mesh lines the inside to reduce abrasion and provide long-term comfort. Each piece of the ExoTech™ system fastens and adjusts quickly with durable polypropylene and elastic straps with Velcro® closures, allowing a custom fit for a wide variety of body types. Comes with a high-quality, durable nylon gear bag for storage and transport. Upper Body & Shoulder Protector • PE (polyethylene) outer shell • L2500 EVA foam & 3mm PE (polyethylene) plate chest/back/arm padding • EVA foam & PE plate shoulder padding • Sponge foam & polyester tricot chest/back/shoulder lining • Mesh chest/back/shoulder outer covering • Mesh arm protector lining • Double riveted PP (polypropylene) connector straps and Velcro® fasteners • Adjustment Straps: Commercial grade elastic with Velcro® fasteners Forearm Protector • PE (polyethylene) outer shell • EVA foam & PU (polyurethane) sponge padding • Mesh inner lining • 420-denier nylon outer

		covering • Commercial grade elastic adjusters with Velcro® fasteners Thigh/Groin Protector Thigh Section: • PE (polyethylene) outer shell • Laminated EVA foam & L2500 EVA foam • Mesh inner lining • 150-denier polyester outer covering • Elastic adjusters with Velcro® fasteners Groin Section • EVA foam padding with mesh outer covering • Inner PE (polyethylene) shell • Commercial grade elastic adjusters and connectors Hard-Shell Shin Guards • PVC (polyvinyl carbonate) knee cap • EVA foam knee padding • 600d black polyester outer covering • Tricot & sponge knee & foot protector inner lining • PE (polyethylene) knee and foot protector outer shell • PVC (polyvinyl carbonate) padded suspension braces • Polyester adjusters with Velcro® fasteners • Adjustable/removable foot protector • Padded ankle protector • All components are riveted to outer shell

8a

Developed by: Redman

Weight: 10.5 lbs

Cost: unknown

Material: Hard outer shell with padded inner material

Coverage: Upper body, upper limbs, lower limbs

Extent Used by Current Forces: not used by infantry but this technology could possibly be modified.

Compatibility: not designed to be compatible with current infantry gear

Reference: http://www.botac.com/refirige.html

Redman Firstline Riot Gear

DRS 180

Product Description:

Designed specifically for law enforcement mobile field force applications and crowd control, the DRS 180 provides coverage to the most vulnerable areas of the body: arms, legs and torso. It doesn't interfere with your duty belt, and you can still wear ballistic or stab resistant vests underneath, as well as other duty gear like a load bearing vest, and thigh holster.

The DRS 180 provides maximum blunt-trauma protection with comfort and mobility. With a triple layer construction featuring an outer lining covered with patented Nomex fabric, inner layers featuring a closed-cell foam construction with a trauma plates sandwiched between the foam for added protection and an inside lining made with a patented, waterproof polyurethane-coated nylon that makes the DRS impervious to blood-borne pathogens, and can be cleaned and disinfected after each use. Contoured design and adjustable straps make it comfortable, flexible and easy to put on.

		The DRS 180 suit is designed as a complete System for crowd management and includes the DRS 180 Torso, DRS 180 Legs and DRS 180 Elbows. **DRS 180 Features** • Easily accommodates existing body armor, a load-bearing vest, and fully equipped duty belt. • Flexible and lightweight, the DRS 180 promotes freedom of movement, and easy access to your equipment. • Inside fabric is impervious to blood-borne pathogens, with anti-bacterial, anti-fungal properties. • Proprietary molded closed-cell foam and inner Trauma Plate offers enhanced layered protection. • Contoured design and cut of the chest guard allows for easy shoulder stocking of weapon. • Inside area of suit is lined with Dartex, a patented, waterproof polyurethane-coated nylon that is easily sanitized. • Convenient one-person operation for putting on/taking off suit. • Flame-resistant, water-resistant, easy-to-clean outer layer of patented Nomex® fabric. • Lightweight and durable.

8b	 	**Developed by:** Redman **Weight:** 21 lbs **Cost:** unknown **Material:** Hard outer shell with padded inner material **Coverage:** Upper body, upper limbs, lower limbs, groin, lower back and buttocks **Extent Used by Current Forces:** not used by infantry but this technology could possibly be modified. **Compatibility:** not designed to be compatible with current infantry gear **Reference:** http://www.botac.com/refirige.html
	Redman Firstline Riot Gear **DRS 360**	**Product Description:** The DRS 360 safeguards against various blunt trauma assaults. Used for cell extractions, snatch & grab teams and front-line riot/crowd control. The design acts as a powerful visual deterrent, and discourages grabbing and clutching by an inmate due to the "no-grip" design. Triple layer construction outer lining is patented Nomex fabric, which is flame resistant, treated to be water resistant, and easy to clean. Inner layers feature closed-cell foam with trauma plates sandwiched between the foam for added protection. The inside lining is made with a patented, waterproof polyurethane-coated nylon that is impervious to blood-borne pathogens and can be cleaned and disinfected after each use. Contoured design and adjustable straps make the DRS comfortable, maneuverable and easy to put on. The DRS 360 suit is designed as a complete System for Corrections Applications and includes the DRS 360 Torso, DRS 360 Legs and DRS 360 Arms. If you are interested in one or more components check out our Modular Configurations

		DRS 360 Features • Flame-resistant, water-resistant, easy-to-clean outer layer of patented Nomex® fabric. • Proprietary molded closed-cell foam and inner shielding offers enhanced layered protection. • Inner layers feature hard shells sandwiched between foam for the added protection of both officer and inmate. • Flexible and lightweight, the DRS 360 promotes freedom of movement, even in close quarters. • Easier movement means more efficient prisoner control, lessening the likelihood of inmate injury. • Easily accommodates existing body armor. • Inside lining of suit is Dartex, a patented, waterproof, polyurethane-coated nylon that is easily sanitized. • Lining is impervious to blood-borne pathogens, with anti-bacterial, anti-fungal properties. • Convenient one-person operation for putting on/taking off suit. • Lightweight and durable.

Upper Limb Protection

1		**Developer:** Paraclete
		Weight: unknown **Cost:** $122.68 **Material:** Dyneema, Goldfles, and Twaron (soft armor) **Coverage:** shoulders **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.order-gear.com/subcatmfgprod.asp?0=421&1=423&2=-1&6=1
	Shoulder Protectors with Soft Armor	**Product Description:** Shoulder Protectors with Soft Armor

2		**Developer:** Paraclete
		Weight: plate:1.1 lbs (0.5 kg) **Cost:** $81.41 pair **Material:** mild steel core **Coverage:** shoulders **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.order-gear.com/product.asp?0=421&1=423&3=4628
	Shoulder Protectors with Hard Armor	**Product Description:** Protection: Single hit, 7.62 x 39, mild steel core. 6" x 6" curved hard plate weighs 1.1 lbs. Plate fits into removable shoulder pockets with soft armor component, and inside the side wings of the RAV.

3		**Developer:** Paraclete
		Weight: unknown **Cost:** $396.88 **Material:** unknown **Coverage:** Biceps **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.order-gear.com/product.asp?0=421&1=423&3=4613
	Bicep Protectors with Armor	**Product Description:** Bicep protectors with armor.

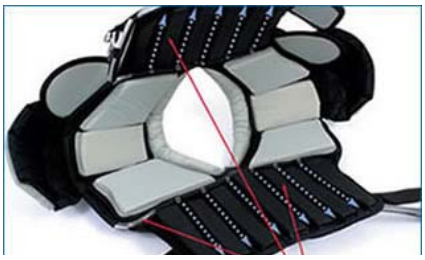
4	 	**Developer:** Sandia National Laboratories (Lockheed Martin company) **Weight:** unknown **Cost:** unknown **Material:** Kevlar with carbon composite **Coverage:** Wrists to shoulders **Extent Used by Current Forces:** Field tested in Iraq by 1-82 FA, 1st Cavalry Division out of Ft. Hood, Texas; 515th Corps Support Battalion, 720th Transportation Company; and the US Air Force 355th Logistics Readiness Squadron/CCDE **Compatibility:** unknown **Reference:** http://www.sandia.gov/news-center/news-releases/2004/gen-science/gauntlet.html http://www.military.com/soldiertech/0,14632,Soldiertech_Gauntlet,,00.html
	Sandia Gauntlets	**Product Description:** Researchers at the National Nuclear Security Administration's Sandia National Laboratories have created gauntlets that will protect the upper limbs of military personnel riding atop Humvees and other military vehicles during combat. The shoulder-length Sandia Gauntlets are made of layers of heavy Kevlar — reinforced material used in bulletproof vests and tires — with carbon-composite forearm and upper arm protective inserts. The heat protection characteristics of the Kevlar layers mitigate the thermal effects of warhead blasts on tissue, while the combination of carbon-composite and Kevlar diminish both blunt trauma effects and penetration or shredding effects of warhead shrapnel on both tissue and bone.

5		**Developer:** Tactical and Survival Specialties Inc
		Weight: unknown **Cost:** unknown **Material:** unknown **Coverage:** Biceps **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.tacsurv.com/TSSIPortal/DesktopDefault.aspx?tabid=318
	Bicep Protector	**Product Description:** Level IIIA optional ballistic bicep protectors. Connects to either the Shadow or Spear Point tactical vests using a sewn connection loop and velcro adjustable strap. Velcro tab can be used to display flags and other forms of identification. Also includes MOLLE weave for connecting pouches.

6		**Developer:** Arnold Engineering UK **Weight:** unknown **Cost:** unknown **Material:** ABS Thermoplastic **Coverage:** Forearm/Elbow **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.arnold-ppe.com/limbproducts.htm#Anchor-AFE1-51540
	Forearm/Elbow Protector	**Product Description:** Constructed from high impact ABS thermoplastic mouldings lined with impact absorbing foam laminate. The outer skin being user friendly for extra comfort. The AFE1 protects the forearm and elbow. It is secured to the forearm by 50mm wide elasticated straps and to the elbow by a 30mm wide elasticated strap, all with velcro fastenings. Straps are riveted to ABS with non-rust rivets. The AFE1 is available in 2 performance levels - Level 1 and Level 2 and in 3 sizes.

7		**Developer:** Arnold Engineering UK **Weight:** unknown **Cost:** unknown **Material:** ABS Thermoplastic **Coverage:** Upper Arm **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.arnold-ppe.com/limbproducts.htm#Anchor-AFE1-51540
	Upper Arm Protector	**Product Description:** Constructed from high impact ABS thermoplastic moulding lined with impact absorbing foam laminate. The outer skin being user friendly for extra comfort. The AUA1 is designed to be worn with the Forearm/Elbow Protector and gives excellent protection to the area between the elbow and the shoulder. It is secured to the arm by a 50mm wide elasticated strap with velcro fastenings. The strap is riveted to ABS by non-rust rivets. The AUA1 is available in 2 performance levels - Level 1 and Level 2 and in 3 sizes.

8	 Deltoid/Upper Arm  Axillary/Under Arm	**Developer:** PEO Soldier **Weight:** 5 lbs (for set) **Cost:** unknown **Material:** unknown **Coverage:** Upper Arm and shoulders **Extent Used by Current Forces:** US Army fielded 50,000 sets in 2004. USMC fielded 33,000 similar sets called Armor Protection Enhancement System (APES). **Compatibility:** compatible with Interceptor OTV **References:** http://www.findarticles.com/p/articles/mi_m0IAV/is_4_93/ai_n6362158 http://www.globalsecurity.org/military/systems/ground/interceptor.htm http://www.nationaldefensemagazine.org/issues/2005/oct/amid_bursting.htm
	Deltoid and Auxillary Protectors (DAPs) for Interceptor Body Armor (IBA)	**Product Description:** DAP consists of two ambidextrous modular components, the Deltoid (upper arm) Protector and the Axillary (under arm) Protector. The Deltoid Protector attaches at the shoulder of the OTV and is secured around the wearer's arm with a strap. The Axillary Protector is worn under the OTV and is attached to the underside of the shoulder portion of the OTV and to the interior adjustment strap on the lower side of the OTV. The DAP provides the same level of protection as the OTV. They are issued in sets of two each.

9	 	**Developer:** Williams Sport Group **Weight:** unknown **Cost:** $50 to $300 **Material:** Polycarbon exterior with pads **Coverage:** Shoulders and upper torso **Extent Used by Current Forces:** N/A: (Sport use) **Compatibility:** N/A (Sport Use) **Reference:** www.footballshoulderpads.com
	Football Shoulder Pads	**Product Description:** The PL17 DB is designed to offer excellent protection and mobility for the hard hitting cover defensive back. Using the shell design of the Pro Level QB / WR, the PL17 DB has a 3/4" "Air Management" main body cushion as well as Personal fit 3/4" removable channels. Sewn on axillary cushions offer added prtection to the frontal deltiod region. A 1" belt system is standard for that all secure fit needed for the hard hitting DB. The mobility that you have in this pad is excellent for DB coverage responsibilities.

10		**Developer:** Adams USA
		Weight: unknown **Cost:** $20 **Material:** Fabric **Coverage:** Hand, Forearm, Elbow **Extent Used by Current Forces:** N/A (Sport Use) **Compatibility:** N/A (Sport Use) **Reference:** www.cbssportsstore.com
	Football Forearm Pads	**Product Description:** For added protection against the toughest tackles and hits. Protects hand, forearm, and elbow. Adult sizes.

11		**Developer:** Adams USA
		Weight: unknown **Cost:** $14 **Material:** Fabric **Coverage:** Elbows, upper arms, and forearms **Extent Used by Current Forces:** N/A (Sport use) **Compatibility:** N/A (Sport Use) **Reference:** www.cbssportsstore.com
	Football turf sleeves	**Product Description:** McDavid 487R football turf sleeves showcase a comfortable elastic sleeve design to help provide durable protection for your elbows and forearms from minor bumps and turf burns.

12		**Developer:** Approved Gas Masks
		Weight: unknown **Cost:** $73 **Material:** goatskin leather, plastic hard plates, foam padding **Coverage:** hands and forearms **Extent Used by Current Forces:** unknown **Compatibility:** unknown **Reference:** http://www.approvedgasmasks.com/gloves-dominator.htm
	Dominator Riot Control Gloves	**Product Description:** Designed to provide protection to law enforcement and corrections officers during volatile crowd control situations and cell extractions. Large foam padded gauntlets with plastic trauma plates protect the forearm, while ¼ inch thick closed-cell foam pads, divided to allow sufficient hand mobility, cover the back of the hands and fingers (indexes are left unpadded for trigger control). The entire hand is protected from sharp weapons by a cut resistant 100% Spectra® knit liner. Constructed with durable finished goatskin leather. • Available in sizes med, lrg, xlrg • Also available, original version without Spectra® Liner (RG700)

13		**Developer:** Approved Gas Masks **Weight:** unknown **Cost:** $20 **Material:** kevlar **Coverage:** hands and forearms **Extent Used by Current Forces:** unknown **Compatibility:** unknown **Reference:** http://www.chiefsupply.com/Law_Enforcement/Crowd_Control/Personal_Protection/K25
	Damascus K25 Kevlar Sleeves	**Product Description:** Damascus K25 Sleeves are lightweight, slip-on protection for your arms. 2-ply Kevlar material resists cuts, scratches and tears Sleeves can be worn over or under other clothing Thumb holes keep sleeves in place Sold in pairs Sizes: S/M (16") or L/XL (19") Color: Black

Lower Limb Protection

1		**Developer:** Arnold Engineering UK **Weight:** unknown **Cost:** unknown **Material:** ABS Thermoplastic **Coverage:** Thigh **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.arnold-ppe.com/limbproducts.htm#Anchor-AFE1-51540
	Thigh Protector	**Product Description:** Constructed from high impact ABS thermoplastic moulding lined with impact absorbing foam laminate. The outer skin being user friendly for extra comfort. The ATH1 gives protection to the front and side of the thigh and is designed to be worn with a Shin/Knee Protector. It is secured to the thigh with a 50mm wide elasticated strap and to the trouser belt by a 30mm wide webbing strap, both straps have velcro fastenings. The straps are riveted to ABS with non-rust rivets. The ATH1 is available in 2 performance levels - Level 1 and Level 2 and in 3 sizes.

2		**Developer:** Protech
		Weight: unknown **Cost:** unknown **Material:** Aramid plain weave ballistic material, carrier made of ballistic nylon **Coverage:** Shin **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.tacsurv.com/TSSIPortal/DesktopDefault.aspx?tabid=345
	Ballistic Shin Guards	**Product Description:** • Rated Level IIIA and designed to defeat 9mm FMJ 124 grain at 1400 fps and .44 magnum, 240 SWC gas check at 1400 fps. • Aramid plain weave ballistic material with diamond stitching to minimize bunching and minimize trauma • Adjustable elastic and velcro to secure to the leg • Carrier made of ballistic nylon with water repellent coating • One size fits all

3		**Developer:** Armtech Corporation **Weight:** 4 lbs (1.8 kg) per leg **Cost:** unknown **Material:** unknown **Coverage:** Shin, knee, ankle **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.tacsurv.com/TSSIPortal/DesktopDefault.aspx?tabid=345
	Ballistic Leg Armor	**Product Description:** • Flexible knee and ankle joints make it easy to kneel or run • Foam pads under each rigid section for impact protection • Weighs less than 4 lbs per leg • Wide straps for comfortable and secure attachment with Quick Release U/L approved fasteners • Hard shell surface has multiple hit capability 3" on center • Black matte finish

4	 	**Developer:** Arnold Engineering UK **Weight:** unknown **Cost:** unknown **Material:** ABS Thermoplastic **Coverage:** Shin, knee, ankle **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.arnold-ppe.com/limbproducts.htm#Anchor-AFE1-51540
	Ballistic Leg Armor	**Product Description:** Constructed from high impact ABS thermoplastic moulding lined with impact absorbing foam laminate. The outer skin being user friendly for extra comfort. The ALK2 gives complete protection for the ankle, shin and knee. Secured to the shin by 50mm wide webbing straps and a 30mm wide elasticated strap around the knee, all with velcro fastenings. Straps are riveted to ABS with non-rust rivets. The ALK2 is available in 2 performance levels - Level 1 and Level 2 and in 3 sizes.

5		**Developer:** API
		Weight: unknown **Cost:** $40 to $100 **Material:** Hard polycarbon exterior with padding **Coverage:** Kneed and shin **Extent Used by Current Forces:** N/A (Sport use) **Compatibility:** N/A (Sport Use) **Reference:** www.apihockey.com
	Hockey Shin Guards	**Product Description:** hockey shin guards.

6		**Developer:** Damascus Protective Gear **Weight:** unknown **Cost:** unknown **Material:** Gel foam centre core with hard shell non-slip cap **Coverage:** Knees **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.damascusgear.com/section/news/pr/1206.html
	DKX-1 Vortex Knee Pads	**Product Description:** DKX-1 VORTEX™ from DPG : Damascus Protective Gear® have a hybrid construction which combines high and low density materials, while the contoured ergonomic shape offers knee pad support. Its GEL and GEL foam center cores contain two types of shock-absorbing gels bonded together to create comfort. The GEL also absorbs body weight and disperses it within the pad. The DKX-1 features a heavy-duty, hard-shell composite cap which is truly NON-SLIP and plants you firmly on any surface. The GEL cores and the unique caps then work together to produce knee zone protection from blunt force trauma. Perforated breathable neoprene coated with silicon at the tops of the pads hug the leg above the knee. 1000 denier nylon Cordura® braces and protects the rest of the knee area. Both straps feature silicone coated strips to prevent pads from slipping in motion. The knee pads are lined and protected with AEGIS Microbe Shield® which controls bacteria and fungus that cause odor, staining, and material deterioration. The ergonomic design of the DKX-1 as a unit conforms to the knees and produces mobility. The pads have been designed specifically for law enforcement and military.

7		**Developer:** Galls **Weight:** unknown **Cost:** $20 **Material:** polyester and polyethylene **Coverage:** Knees **Extent Used by Current Forces:** Unknown **Compatibility:** developed as riot gear for Police however it could possibly be redesigned for military use **Reference:** http://www.galls.com/style.html?assort=general_catalog&style=TE261&cat=3035
	Hardshell Articulated Knee Protector	**Product Description:** Outer hardshell Soft, comfortable interliner Guaranteed ease of movement Protects against thrown rocks, bottles, sticks and other objects Made of polyester and polyethylene foam Black One size fits all Imported

Other Protection

1		**Developer:** Paraclete
		Weight: unknown **Cost:** $81.29 **Material:** Dyneema, Goldfles, and Twaron (soft armor) **Coverage:** Throat Protection **Extent Used by Current Forces:** Unknown **Compatibility:** attaches to RAV or MTV ballistic / tactical vest **Reference:** http://www.order-gear.com/subcatmfgprod.asp?0=421&1=423&2=-1&6=1
	Front Yoke	**Product Description:** Throat protection

2		**Developer:** Inter-American Security Products Inc
		Weight: unknown **Cost:** $145 **Material:** unknown **Coverage:** Neck and Shoulders **Extent Used by Current Forces:** Unknown **Compatibility:** Worn under vests **Reference:** http://www.interamer.net/index.asp?PageAction=VIEWPROD&ProdID=188
	Neck and Shoulder	**Product Description:** Ballistic Neck and Shoulder Protection Level IIIA This universal fitting neck and shoulder protector provides level IIIA protection to the neck and shoulder. It can be worn under all vests which don't provided this level of protection. The collar and shoulder straps use Velcro to conveniently secure it in place and it provides maximum comfort and protection.

3		**Developer:** MK Technology
		Weight: unknown **Cost:** unknown **Material:** unknown **Coverage:** Neck and Shoulders **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.mktechnology.de/
	Neck and Shoulder	**Product Description:** Neck and Shoulder Protection

4		**Developer:** Army Program Executive Office (PEO), manufactured by Crye Precision
		Weight: 2.9 oz (82 g) **Cost:** unknown **Material:** nylon, cotton fabric, and "ballistic-resilient material" **Coverage:** Back of Neck **Extent Used by Current Forces:** 430,000 units provided to U.S. Army, 75,000 expected to be provided to USMC **Compatibility:** Attaches to back of helmet **Reference:** http://www.bodyarmornews.com/body-armor-news/Army_adding_neck_pad_to_body_armor.htm
	Nape Pads	**Product Description:** The Army is adding another piece to the body armor soldiers wear in combat zones — a small neck pad, which is supposed to protect the back of the neck from shrapnel. The 2.9-ounce pads, which are made out of "nylon and cotton fabric and a ballistic-resilient material," include hook-and-loop fasteners that attach to a rear strap on the helmet. The Marine Corps plans to award a contract for 75,000 nape pads as soon as possible and then begin issuing the pads to the deployed Marines immediately thereafter. The pads provide additional protection from ballistic fragmentation, or shrapnel, that might find its way between the top of the bullet proof vest, and the bottom of a soldier's Kevlar Advanced Combat Helmet. Army officials decided to coordinate testing at an independent ballistics laboratory certified by the National Institute of Justice. The pads passed the tests, and the Army decided to adopt the nape attachment as its eighth improvement in body armor in the last three years.

5		**Developer:** MTek Weapon Systems **Weight:** 1.3 lbs **Cost:** unknown **Material:** unknown **Coverage:** Facial **Extent Used by Current Forces:** Iraq, extent of fielding unknown **Compatibility:** appears compatible with lightweight helmet and ballistic eyewear **Reference:** http://www.mtekweaponsystems.com/home.html http://www.defensetech.org/archives/002147.html
	Face Protector	**Product Description:** The Predator FAST G-Series is a lightweight facial armor system being developed by MTek Weapon Systems for vehicle mounted crew served weapons gunners and other vehicle mounted personnel. It offers maximum protection and visibility, while being light enough to wear all day. It is currently being used in Iraq, by various members of the U.S. Armed Services.

6		**Developer:** Damascus Protective Gear **Weight:** 3 to 8 oz **Cost:** unknown **Material:** "Nomex" **Coverage:** Neck, throat, and head **Extent Used by Current Forces:** unknown **Compatibility:** unknown **Reference:** http://www.damascusgear.com/section/products/hoods/nh250h.html
	SWAT Hood	**Product Description:** 8 oz 100% Nomex Heavyweight hood with flared bib Approximately 18" flared Colors black, green, and tan US Made One size fits all Kevlar version available

7	 	**Developer:** TACARM **Weight:** 7.3 ounces (0.2 kg) each **Cost:** $38 for 1 insert **Material:** unknown **Coverage:** Knees, elbows or hips **Extent Used by Current Forces:** unknown **Compatibility:** Inserts into a standard combat uniform that has been modified with pockets **Reference:** http://www.tacarm.com/bcucoat.htm
	Knee / Elbow / Hip Inserts	**Product Description:** The Ballistic Combat Uniform ™ coat will provide IED protection to many areas of the torso and arms that are not covered by bullet-resistant vests. Current issue ballistic vests leave the upper arms, elbows, lower back and hips exposed to deadly projectiles and fragments. The modified Army Combat Uniform (ACU) coat has Shrapnel Shield ™ ballistic panels inserted that protect the upper body. The BCU coat is comfortable in all tactical positions to include sitting down in a vehicle.

8		**Developer:** Tactical and Survival Specialties Inc
		Weight: Unknown **Cost:** unknown **Material:** unknown **Coverage:** Groin **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.tacsurv.com/TSSIPortal/DesktopDefault.aspx?tabid=318
	Groin Protector	**Product Description:** Level IIIA optional ballistic groin protector connects to either Shadow or Spear Point tactical vests using side release buckles.

9		**Developer:** Pacific Safety Products Inc
		Weight: Unknown **Cost:** unknown **Material:** unknown **Coverage:** Groin **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.pacsafety.com/products/2140.htm#
	Optional Additional Collar, Shoulder, and Groin armor protection	**Product Description:** **Groin Protection:** Protects vulnerable groin and femoral area. Pull down design keeps the groin protector out of the way for mobility, but is easily deployed when needed. Armor protection is the same threat configuration as ballistic panels (extra charge) **Collar Protection:** Provides necessary additional neck protection when in prone firing position. Armor protection is the same threat configuration as ballistic panels (extra charge) **Arm Protection:** Detachable and adjustable with ring-feed hook and loop strap at the center of the shoulder. Armor protection is the same threat configuration as ballistic panels (extra charge).

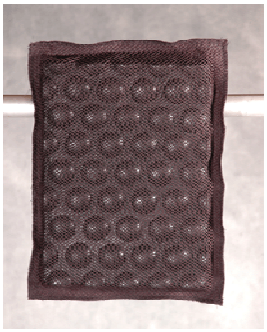
10	 	**Developer:** Protective Products International / TAG / Source One **Weight:** approx 0.5 lbs (0.2 kg) **Cost:** unknown **Material:** Soft Armor **Coverage:** Lower Back **Extent Used by Current Forces:** Ordered with the USMC MTV (2007) to be used in Iraq. **Compatibility:** Attached to USMC MTV (2007) **Reference:** TACK, D.W. et. al. (2006). Marine Corps Modular Tactical Vest Field User Evaluation. Prepared for United States Marine Corps Systems Command – Quantico N00173-06-C-2064
	Lower Back Extension	**Product Description:** Soft armor, lower back protection.

11		**Developer:** Protective Products International / TAG / Source One
		Weight: size S/M: 4 lbs (1.8 kg) per plate, soft armor insert, and pocket **Cost:** unknown **Material:** Kevlar Hard Armor plate and soft armor insert **Coverage:** Sides of Torso **Extent Used by Current Forces:** Currently used by USMC in Iraq **Compatibility:** Attaches to USMC MTV (2007) and Interceptor OTV **Reference:** TACK, D.W. et. al. (2006). Marine Corps Modular Tactical Vest Field User Evaluation. Prepared for United States Marine Corps Systems Command – Quantico N00173-06-C-2064
	Side SAPI plates	**Product Description:** Hard armor ballistic side plate integrated into tactical vest.

12		**Developer:** FEDUR S.A. (Spain)
		Weight: unknown **Cost:** unknown **Material:** Hard armor plate, ceramic, flexible/twistable **Coverage:** Unknown. Not currently NIJ certified. **Extent Used by Current Forces:** Unknown **Compatibility:** SAPI body armor to be inserted into ballistic vests **Reference:** http://www.fedur.com/index.php
	Flexible Plates	**Product Description:** A flexible, twistable hard armor SAPI plate. Level IIIA protection.

13		**Developer:** MK Technology.
		Weight: unknown **Cost:** unknown **Material:** unknown **Coverage:** Lower abdomen, thighs, groin, buttocks **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** www.mktechnology.de
	Protective Pants	**Product Description:** Male and female pants available. Two side thigh protection Integrated abdomen protection Cut and stab resistant at groin and inside thighs Integrated shock absorber All protectors removable by zippers

14		**Developer:** Mawashi
		Weight: 0.5 Kg plus 0.725 Kg battery belt **Cost:** unknown **Material:** unknown **Coverage:** chest and/or back **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.mawashi.net/products
	CSV-5 Active Cooling System	**Product Description:** This system is designed to reduce the human body temperature so that a person wearing additional personal protective equipment may more safely withstand adverse heat conditions. This system may also be used simply to increase the comfort of a person in hot environments. The system comprises at least one panel designed to be worn under protective clothing or any other kind of clothing. Each panel is configured to be worn on the chest or the back of the user and can be worn in direct contact with the skin or over a light undergarment. These panels are connected together using a strap and fastening configuration. The coverage area for the cooling panels is optimized for the chest and back regions and they can be made in various sizes and shapes to fit a wide range of people. The system includes a dry cell battery (an even weight distribution battery belt) with 8 hours of autonomy.

15	 	**Developer:** Mawashi **Weight:** 0.3 Kg **Cost:** unknown **Material:** unknown **Coverage:** chest and/or back **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** http://www.mawashi.net/products
	PCS-3 Passive Cooling System	**Product Description:** This system is designed to reduce the human body temperature so that a person wearing the system may more safely withstand adverse heat conditions and/or to increase overall comfort. As with the CSV-5 system the PCS-3 is comprised of chest and back panels that are worn in direct contact with the body or over a light undergarment. The same strap and fastening system is used to maintain the panels in proper position and the passive system panels are also available in a range of sizes and shapes to facilitate improved fit and comfort for the user. Overall, this personal cooling system influences the rate of evaporation of water vapour from the skin without the assistance of an active mechanical system. The phase change of sweat liquid to vapour is accelerated and the suction created in the space between the panels and the body of the user also draws more humidity and heat away from the body.

16	No picture available	**Developer:** Pacific Safety Products
		Weight: unknown **Cost:** unknown **Material:** unknown **Coverage:** unknown **Extent Used by Current Forces:** Unknown **Compatibility:** unknown **Reference:** unknown
	Vest Stand-off and Waist Belt	**Product Description:** TBD

Annex B: PPE Trial Plan

1 Background

The nature of the threat from Improvised Explosive Devices (IED) has changed the pattern and probability of injury for both mounted and dismounted personnel. Some potential IED effects might not have been accounted for in current designs of Personal Protective Equipment (PPE). The synergistic effects of close-in blast, high density fragmentation and larger fragments have required that armor coverage and the level of protection be revisited.

In order to develop PPE recommendations to overcome any change or increase in vulnerability, and to assess the associated physiological and mobility trade-offs, the impact of increasing PPE needs to be assessed against soldier performance. A human factors trial is proposed to investigate the trade-off between PPE protection (coverage and level) and soldier task performance, acceptance, and comfort.

2 Aim

The aim of this PPE trial is to investigate soldier mobility, survivability, and lethality under various coverage and protection levels for the torso and extremities. The trial will consider soldier task performance as well as soldier acceptance and comfort.

3 Method

A 3 day PPE trial will be undertaken at a Canadian Forces (CF) army base. Approximately 16 CF personnel (minimum 12) will be required to undertake a battery of human factors tests while comparing seven PPE variations.

To better understand the impact of increasing PPE coverage and levels on soldier performance in combat tasks we must first investigate and understand the implications of added weight and joint coverage on discrete activities and soldier capabilities. We propose to undertake a step-wise methodology (see Figure 1). As a first step, we will characterize the relative burden of any PPE change on the soldier in terms of weight, coverage of the body, and obstruction of body joints. The PPE burden for all seven variants will be assessed for each participant relative to their body shape, size, and weight. The next step will include an assessment of discrete mobility activities that reflect the actions and movements common in combat tasks. These discrete mobility activities will include tests of speed, agility, endurance, and range of joint motion. Finally, in the last step, we will investigate the effect of PPE changes on combat task performance. Combat tasks will include traversing obstacles, evading fire and returning fire to both prone and kneeling positions of cover, and vehicle evacuation.

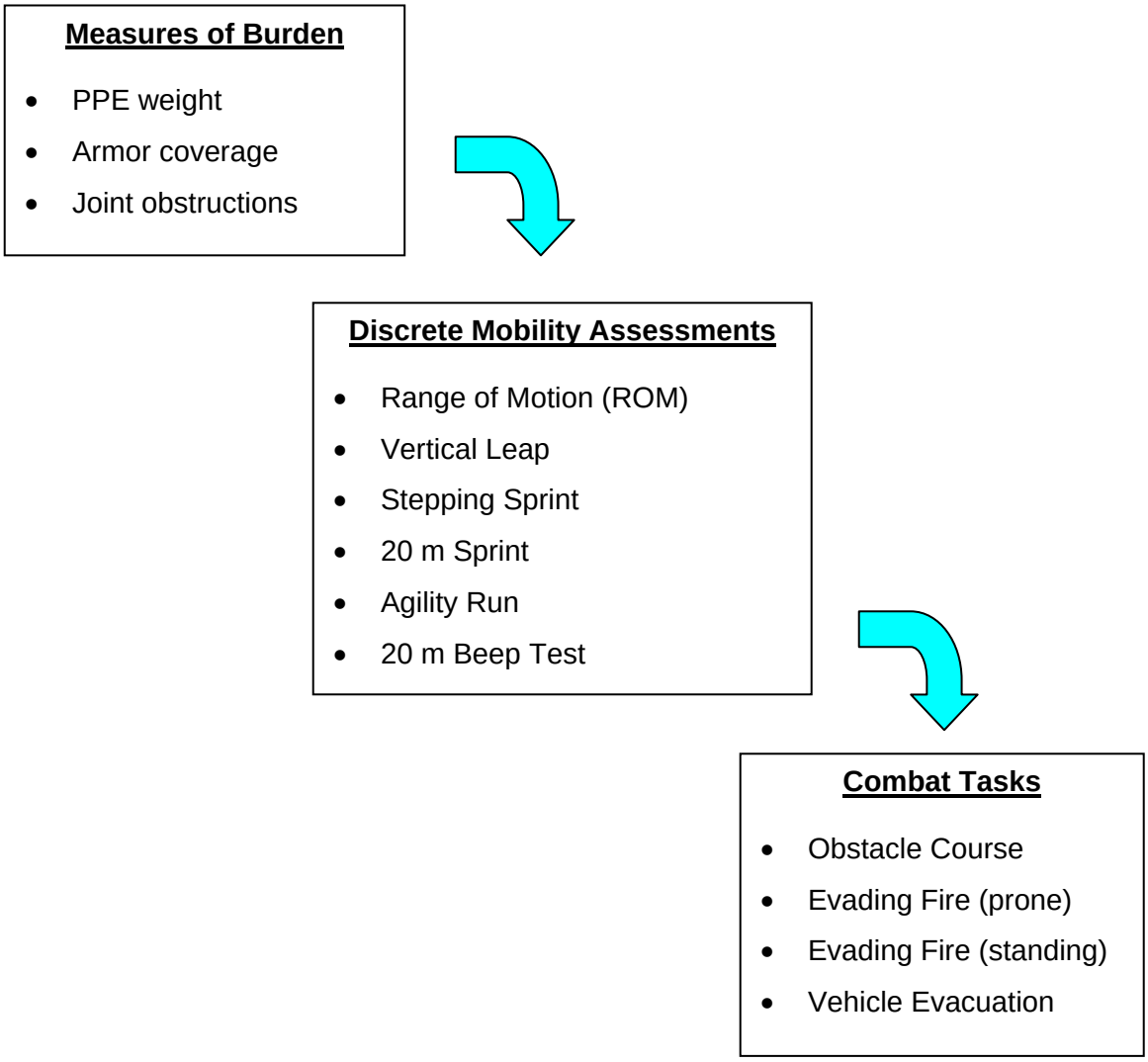


Figure 1: Step-wise Test Methodology

Using this step-wise approach we will be able to relate the outcome soldier performance on combat tasks to performance in antecedent activities and to the relative extent of weight and armour coverage effects on the soldier. In this way, a more causal relationship can be established between the characteristics of PPE and the resulting effects on soldier performance.

3.1 PPE Variations

Diagrams of exemplar infantry equipment is presented for seven PPE Ensembles in Annex A. The ensembles range from maximum mobility (least protection) to maximum protection (least mobility).

3.2 Description of Step-wise Tests

The specific tests and measurements outlined in the step-wise methodology are described in more detail below for each step.

3.2.1 Measures of Burden

To establish the relative burden of each PPE variants for each soldier participant, anthropometric measurements will be taken at the start of the trial. Body weight of each participant will be compared to the weight of each PPE variation. Body size (stature, neck circumference, chest circumference, waist circumference) will be compared to the amount of armor coverage. Joint obstructions presented by certain PPE ensembles will be assessed by having the participant don the armor to see if the coverage obstructs the movement of joints at the neck, shoulders, elbows, waist, hips, and knees. The amount of obstruction will be assessed on a 5-point scale system as shown in Table 1.

Table 1: Joint Obstruction Level Assessment

Joint Obstruction Level	Description	e.g. Elbow Joint and Upper Arm Brassard
1	Light contact when the joint is flexed and approaching maximum flexion	
2	Light contact when joint is partially flexed	
3	Less than 1cm of contact at all times	

4	1-5 cm of contact area over the joint	
5	Complete joint coverage at all times	

3.3 Discrete Mobility Assessments

Discrete mobility tests will be undertaken in each PPE variant to characterize the performance implications of the preceding measures of burden. Mobility assessments will include a Range of Motion (ROM) test, a vertical leap test, a stepping sprint, a 20 m sprint, an agility run, and a 20 m Beep test. These tests are described in more detail below.

3.3.1 Range of Motion (ROM)

Range of Motion (ROM) of the knee, hip, waist, elbow, shoulder, and neck will be assessed in a static test stand while wearing each of the seven PPE variants. For each joint, participants will be required to assume a fully extended position and then slowly flex to the point at which the subject feels noticable resistance from the PPE (measurement 1) and then to the full extent of flexion possible (measurement 2).

3.3.2 Vertical Leap

Participants will be required to leap vertically as high as possible from a stationary, standing position, while wearing each of the seven PPE variants. This is a standard test of leg power. A measuring tape will be secured to a wall, and the participant will be required to touch the tape at the highest possible point with their dominant hand (Figure 2). The height will be measured by HF staff.

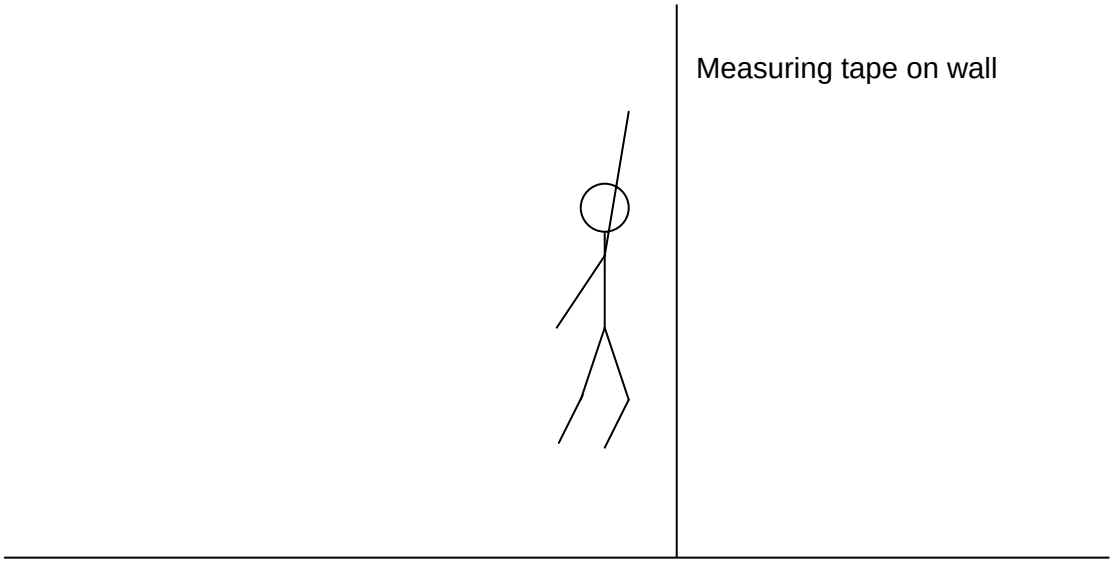


Figure 2: Vertical Leap Test

3.3.3 Stepping Sprint

The stepping sprint will be used as a measure of leg speed while wearing each of the seven PPE variants. Participants will be required to step up and down on a single step (20 cm high). Stepping is performed with a four pace cycle: step up with one foot, step up with the second foot, step down to the ground with one foot, step down with the second foot. Participants are then required to perform each four pace cycle as many times as possible in 30 seconds. The number of steps will be counted and recorded by HF staff. Participants will be required to perform the Stepping Sprint test in all seven PPE variants.

3.3.4 20m Sprint

Participants will be required to sprint 20 m as fast as possible, wearing each of the seven PPE variants. HF observers will record the elapsed time for each sprint.

3.3.5 Agility Run

Participants will be required to run through an agility course of pylons as fast as possible, Figure 3. HF observers will record the elapsed time for each agility run.

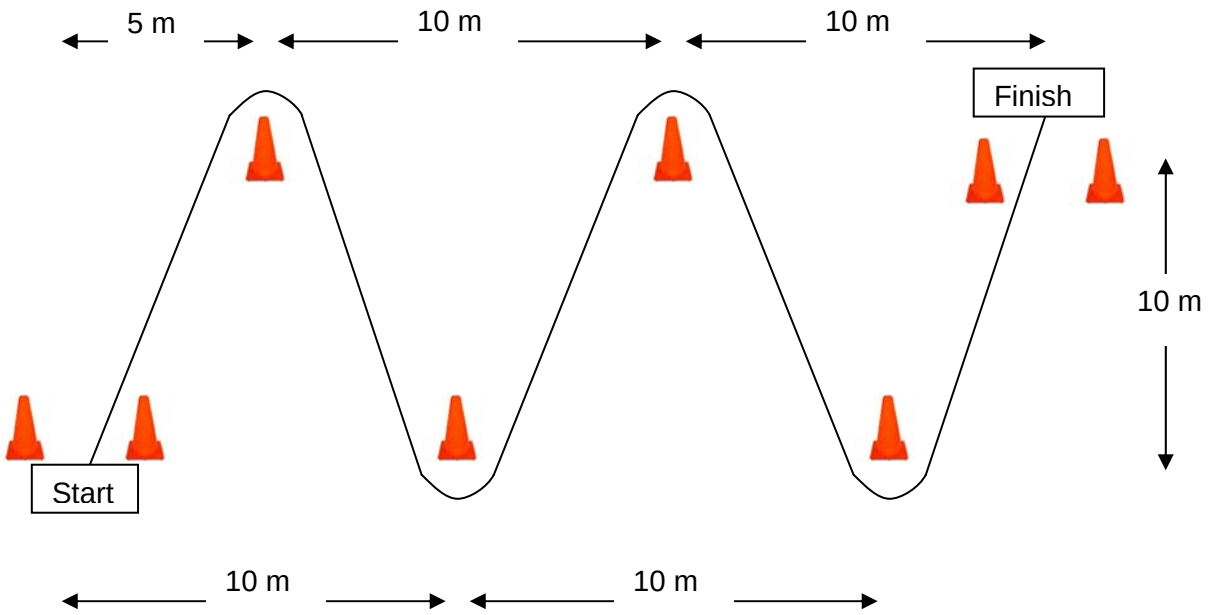


Figure 3: Agility Run Layout

3.3.6 20m Beep Test

The Beep Test is a 20 m multi-stage fitness assessment test designed to measure the aerobic or endurance component of physical fitness. Participants run the 20 m length according to the audio cues (beeps) from a pre-recorded instructional CD (Figure 4). Over time, the duration between beeps is shortened until the runner can no longer cover the 20 m distance in the time available, before the subsequent beep sounds. If the participant is unable to maintain the speed required on two consecutive legs, the runner is retired and their score is recorded by a HF observer. These scores can then be related to normative VO_2 tables for gender and age to derive their fitness level. These VO_2 can then be compared across the seven PPE variants for each participant.

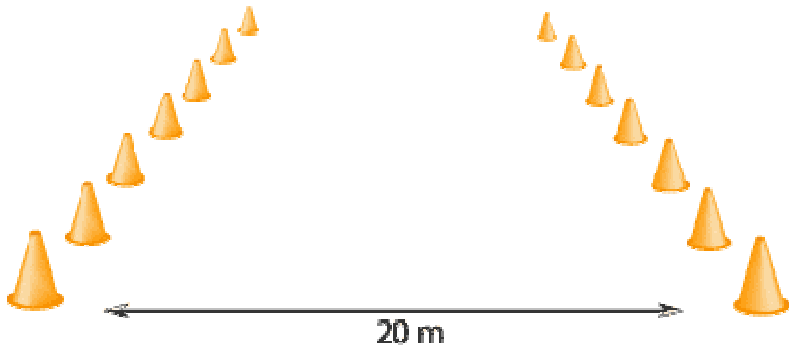


Figure 4: Field Layout for the 20m Beep Test

3.4 Combat Tasks

Soldier performance in a number of combat tasks will be assessed to determine the effect of different PPE levels and coverage on survivability, mobility, and lethality. Combat tasks will include evading and returning fire, obstacle course traverse, and vehicle evacuation.

3.4.1 Evading and Returning Fire: Dive to Prone

Participants will be required to perform a Dive to Prone test while wearing each of the seven PPE variants. The test would be as follows:

1. Participant is walking with their rifle in the ready position along path paralleling a road-side ditch, as shown in Figure 5.
2. An audible signal (horn) sounds at a time that is unpredictable to the participant.
3. From the horn sound, the Participant is required to dash and dive into the ditch and get completely under cover

Objective measure 1: The camera will record the time from when the horn was sounded until the time when the participant is completely out of sight.

4. The Participant will crawl forward to the edge of the ditch and adopt a fire position, as if they were engaging the video camera location.

Objective measure 2: The camera will record the time from when the horn was sounded until the time when the participant is in a fire position engaging the video camera.

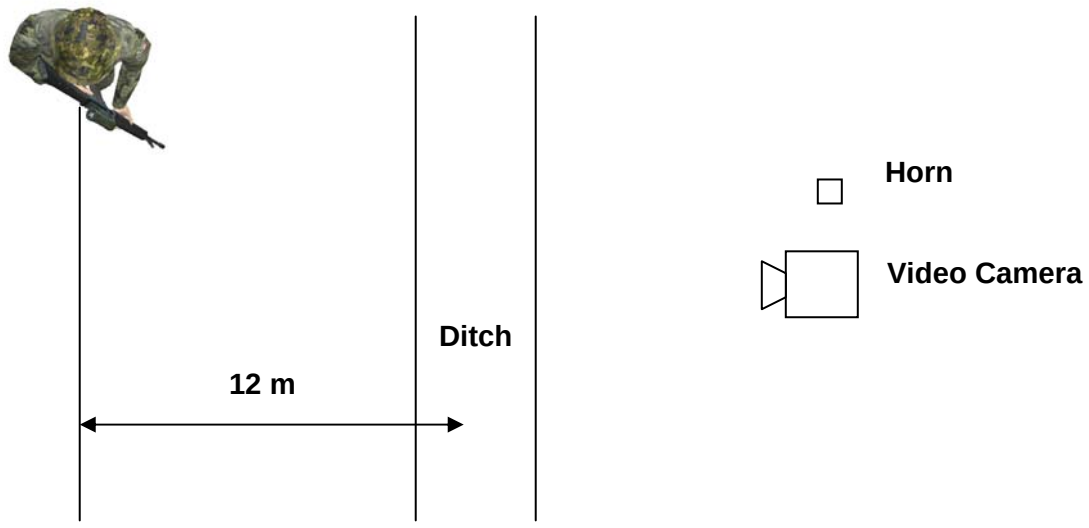


Figure 5: Dive to Prone Setup

3.4.2 Evading and Returning Fire: Dash to Cover

Participants will be required to perform a Dash to Cover exercise in each of the seven PPE variants. The test is as follows:

1. Participant is walking towards the video camera with their rifle in the ready position, along the path shown in Figure 6.
2. An audible signal (horn) sounds at a time that is unpredictable to the participant
3. From the horn sound, the Participant is required to get completely under cover behind one of the walls.

Objective measure 1: The camera will record the time from when the horn was sounded until the time when the participant is completely out of sight.

4. The Participant will move to the edge of the wall and adopt a kneeling fire position, as if they were engaging the video camera location.

Objective measure 2: The camera will record the time from when the horn was sounded until the time when the participant is in a fire position and engaging the video camera location.

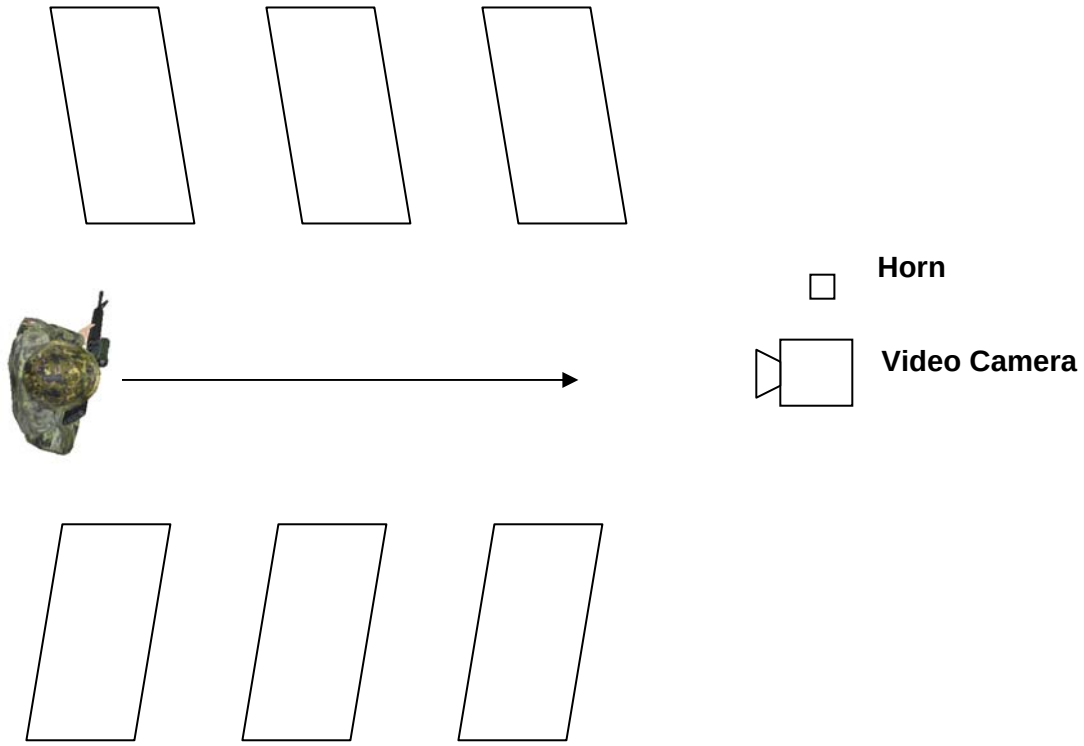


Figure 6: Dash to Cover Setup

3.4.3 Obstacle Course Traverse

PPE effects on soldier performance in obstacle traverse and mobility tasks will be evaluated for all seven PPE variants. Participants will be required to perform a timed course to traverse a series of obstacles (e.g. ladder, low wall, high wall, over-under, mouse hole access, rope climb, and low crawls). Subjective ratings will be collected for each PPE condition.

3.4.4 Vehicle Evacuation

Participants will be required to perfrom driver evacuation and commander hatch evacuation scenarios in each of the seven PPE variants. For the driver evacuation scenario, participants will be required to occupy the driver position of a LAV III and simulate driving tasks. At a time unpredictable to the participant, a horn will sound. The participant will be required to evacuate from the vehicle as fast as possible and a HF observer will record the time from the sound of the horn to the time when the participant is completely out of the vehicle. Occurences of snagging and clash will also be noted.

Similarly, for the commander hatch evacuation scenario, participants will be required to occupy the commander hatch or gunner position of a LAV III and perform a similar evacuation scenario.

3.5 Subjective Performance Measures

The purpose of the subjective performance measures are to assess soldier acceptance and comfort for the various PPE conditions.

Following the mobility, survivability, and lethality tasks participants will be required to complete a Physical Discomfort Questionnaire. This questionnaire comprises drawings of the front and back sides of the torso and extremities. Participants are required to indicate the body location and rate the extent of physical discomfort using the five point rating scale provided. Discomfort could include, but is not limited to, contact irritation or pressure points. HF staff will investigate any reports of discomfort through interviews with affected participants.

Similarly, the thermal demands associated with each PPE condition will be evaluated throughout the trial. Following the mobility, survivability, and lethality tasks, participants will be required to complete a Thermal Discomfort Questionnaire. This questionnaire comprises drawings of the front and back sides of the torso and extremities. Participants are required to indicate the location of any heat build-up and rate the amount of thermal discomfort using the five point rating scale provided.

At the completion of the PPE evaluation activities, participants will be required to directly compare and rate the suitability of the PPE conditions to infantry tasks in an Exit Questionnaire. The PPE conditions will be discussed in detail during an exit focus group to identify concerns and suggestions for improvement.

4 Trial Schedule

Day 1	Day 2	Day 3
In Brief / Safety Brief / Contractor Training / Fit Check & Equipment Check Anthropometry / Joint Obstruction Assessments / Range of Motion	20 m Sprint / Agility Run / 20 m Shuttle Run (Beep Test)	Vehicle Evacuation / Catch up
Lunch	Lunch	Lunch
Vertical Leap / Stepping Sprint	Combat Tasks: Ditch Dive Exercise / Standing Cover Exercise	Subjective Performance Measures (Questionnaires) / Focus Group / Exit Brief

5 Resources

The following resources are requested for this trial. PPE items, required for all days of the trial, are tabulated in Annex A.

5.1 Troop Requirements

Approximately 16 Canadian Forces personnel (minimum 12) will be required from a range of MOS's. The participants will be selected to represent the range of Canadian infantry population. In order to standardize fitness levels, participants must have completed basic training within the last year.

5.2 Facility Requirements

1. **Classroom:** A classroom facility/lecture theatre facility for briefings and focus group discussions. Room to handle up to 25 personnel.
2. **Field:** An outdoor field will be sufficient to perform most of the activities.
3. **Gymnasium:** The Vertical Leap test will require a gymnasium or a room with high ceilings, or alternatively an outdoor wall. It should also be considered that a gymnasium could be used as the classroom and in case of poor weather.
4. **Staircase:** The Stepping Sprint will require a step.
5. **Ditch:** The Ditch Dive exercise will require a ditch beside a grade where a camera can be set up to observe the participant completely out of sight
6. **Vehicle area**: A suitable training area will be required to conduct the vehicle evacuation exercise.

5.3 Equipment Requirements

For the performance of the trial, the following equipment will be required:

- Anthropometric Protractor*
- Measuring tape for the vertical leap test*
- Audio equipment for auditory cueing of the 20m Beep Test
- Recorded beep test*
- Pylons and measuring equipment for layout of the 20 m sprint, Agility run, and 20 m shuttle run (beep test)
- Timers for the stepping sprint 20m sprint and the Agility run*
- Horn for the Ditch Dive Exercise and the MOUT Exercise
- 6 plywood boards on vertical stands for the MOUT exercise
- LAV III or G-Wagon for vehicle evacuation scenarios

* Equipment currently owned by Human*systems*®.

5.4 Personnel

In addition to the 16 participants (minimum 12), the following personnel are required to support this trial:

5.4.1 Trial Support Officer / NCO

Require unit support officer / NCO for unit.

5.4.2 Trial Support Personnel (Pers)

Required to support the trial in a number of areas.

5.4.3 Medical Support Staff (Including Ambulance)

A corpsman, driver and ambulance are required for the duration of the trial.

5.5 Vehicles

A LAV III will be required for the vehicle evacuation exercise

An ambulance will be required for the duration of the trial

5.6 Weapons and Combat Load

Participant will be required to have fighting order load as described in Annex B. C7A1 assault rifles will be required for each participant throughout the course of the trial. No rifle ammunition is required.

5.7 Rations

Rations: Lunch rations are requested for the duration of the trial.

Table 2: Ration requirements

Item	Description	Daily	Total x 3 days
Lunch	IMP	25	75

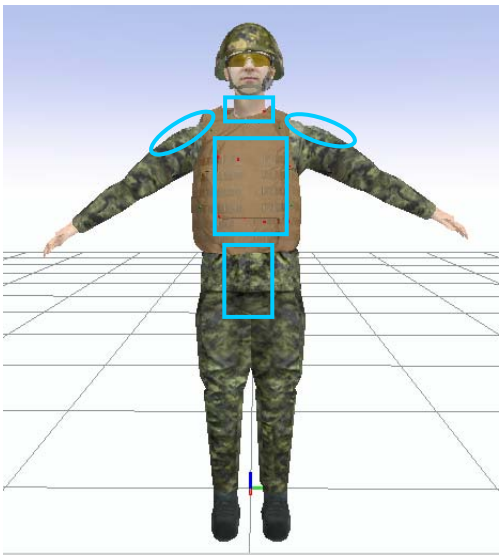
5.8 Other Requirements:

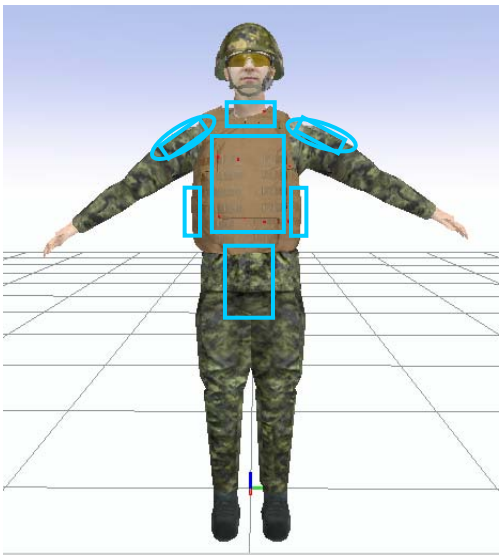
Radios and Net Permissions during the course of the trial. (Note: a set of 4 radios is currently owned by Human*systems*®).

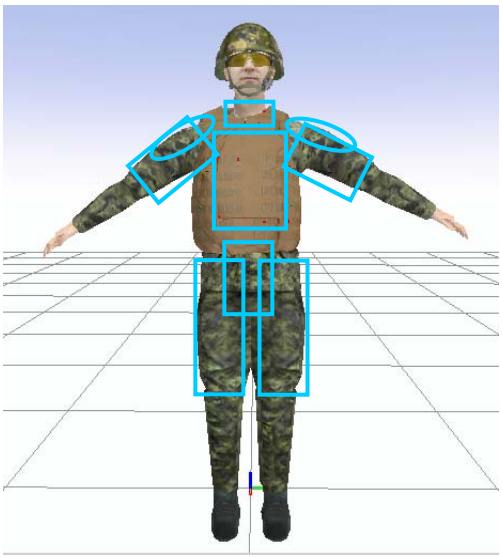
Annex C: PPE Variants

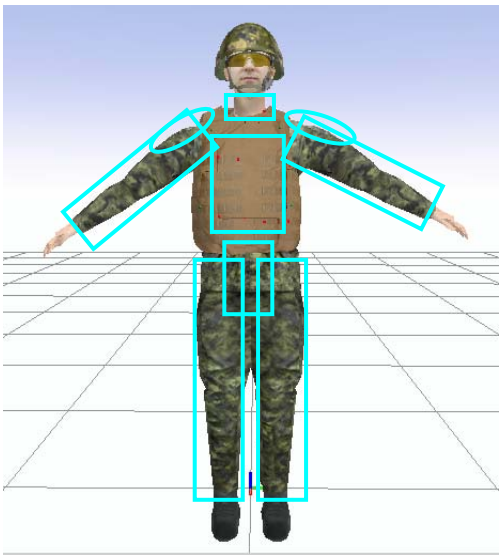
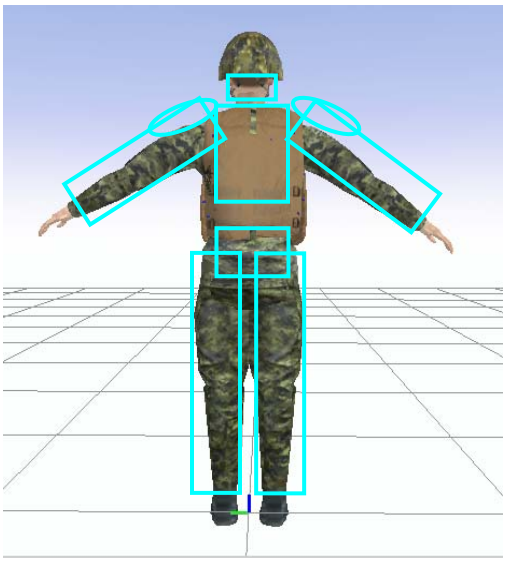
1	**Baseline Equipment:** CG 634 helmet, ballistic eyewear, and tactical vest (no body armor).	 	Maximum mobility, least protection	**Coverage:** head protection.

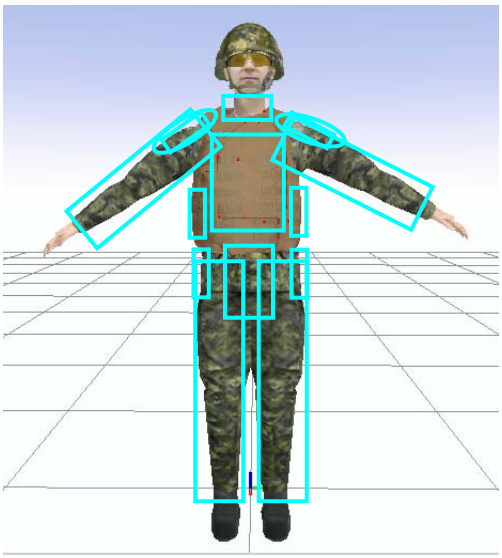
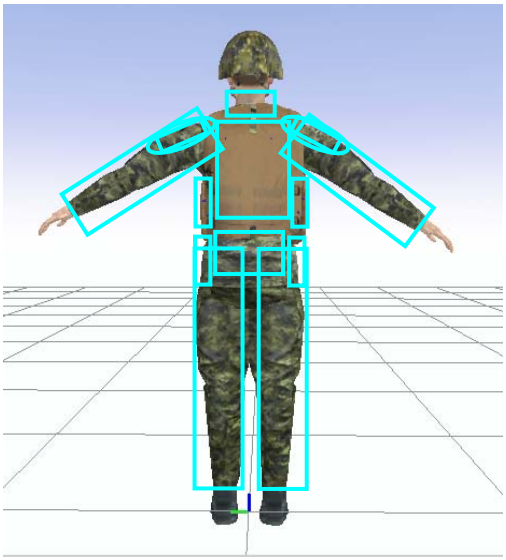
2	**Equipment:** CG 634 helmet, ballistic eyewear, fragmentation protective vest (no hard armor plates), and tactical vest.	 		**Coverage:** head and torso (front/back) protection.

3	**Equipment:** Ensemble 2 plus hard armor front and back plates, soft armor on shoulders/ upper arm, groin protector, throat guard (front of neck), collar (back and sides of neck), and back extension.	 		**Coverage:** head, neck and throat, shoulders/ upper arms, torso front/back, groin, and lower back protection. Small-arms protection for front and back of torso.

4	**Equipment:** Ensemble 3 plus hard armor plates on sides and shoulders.	 		**Coverage:** head, neck and throat, shoulders/ upper arms, torso front/back, groin, and lower back protection. Small-arms protection for front/back/sides of torso and shoulders.

5	**Equipment:** Ensemble 3 plus partial upper and lower limb protection.	 		**Coverage:** head, neck and throat, shoulders, upper arms, torso front/back, groin, lower back, and thigh protection. Small-arms protection for front/back of torso.

6	**Equipment:** Ensemble 3 plus full Upper and lower limb protection.	 		**Coverage:** head, neck and throat, shoulders, upper limbs, torso front/back, groin, lower back, and lower limbs protection. Small-arms protection for front/back of torso.

7	**Equipment:** Ensemble 4 plus upper and lower limb protectors and hard armor thigh protectors.	 	Least amount of mobility, maximum protection	**Coverage:** head, neck and throat, shoulders, upper limbs, torso front/back, groin, lower back, and lower limbs protection. Small-arms protection for front/back/sides of torso, thighs, and shoulders.

Annex D: Combat Load

Table 3: Fighting Order Conditions

Load Order Item	Quantity
C7A1	1
Sling	1
C7 Magazine (with 30 rds)	5 (one on the rifle)
1 Qt. Canteen (filled)	1
M67 HE Grenade	1
HC1A1 Smoke Grenade	2
Bayonet	1
Multi-tool	1
Pen Light	1
Insect Repellent	1
Sunscreen	1
Gloves Temperate	1 pr
Flare Projector	1
Field Dressings	2

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ANALYSE DE POINTE DES OPTIONS EN MATIÈRE D'ÉQUIPEMENT DE PROTECTION INDIVIDUELLE ACCRUE (U)

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

Kent W. McKee ; David W. Tack

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(U) The purpose of this study was to conduct a state−of−the−art review of commercial and military off the−shelf (COTS/MOTS) options for enhancing protection of the soldier's torso, neck, nape and extremities, including any design options from industrial and sports applications. This review was then used to recommend which add−on torso and extremity components should be modeled in Digital Biomechanics software. Finally, detailed requirements for the commencement of a future biomechanical modeling analysis were provided.

(U) Cette étude constitue une analyse de pointe des différents articles offrant une protection individuelle accrue du torse, du cou, de la nuque et des extrémités, disponibles dans le commerce ou militaires standards (COTS/MOTS). Des articles conçus pour l'industrie et les sports ont également été inclus dans l'étude dont les résultats ont permis de recommander quels éléments complémentaires de protection du torse et des extrémités devaient être intégrés au logiciel de modélisation biomécanique. Enfin, on a défini des exigences détaillées pour une future analyse du modèle biomécanique.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Counter−IED; C−IED; Personal Protective Equipment; PPE; Horizon 0; IED Protection;body armour; coverage; protection level